Geophysical Research Abstracts
Vol. 16, EGU2014-3531, 2014
EGU General Assembly 2014

Numerical modelling of the formation of fibrous bedding-parallel veins

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Bedding-parallel veins with a fibrous infill oriented orthogonal to the vein wall, are often observed in fine-grained metasedimentary sequences. Several mechanisms have been proposed for their formation, mostly with respect to effects of fluid overpressures and anisotropy of the host-rock fabric in order to explain the inferred extensional failure with sub-vertical opening. Abundant pre-folding, bedding-parallel fibrous dolomite veins are found associated with the Nkana-Mindola stratiform Cu-Co deposit in Zambia. The goal of this study is to better understand the formation mechanisms of these veins and to explain their particular spatial and thickness distribution, with respect to failure of transversely isotropic rocks. The spatial distribution and thickness variation of these veins was quantified during a field campaign in thirteen line transects perpendicular to undeformed veins in underground crosscuts.

The fibrous dolomite veins studied are not related to lithological contrasts, but to a strong bedding-parallel shaly fabric, typical for the black shale facies of the Copperbelt Orebody Member. The host rock can hence be considered as transversely isotropic. Growth morphologies vary from antitaxial with a pronounced median surface to asymmetric syntaxial, always with small but quantifiable growth competition. A microstructural fabric study reveals that the undeformed dolomite veins show low-tortuosity vein walls and quantifiable growth competition.

Here, we use a Discrete Element Method numerical modelling approach with ESyS-Particle (http://launchpad.net/esys-particle) to simulate the observed properties of the veins. Calibrated numerical specimens with a transversely isotropic matrix are repeatedly brought to failure under constant strain rates by changing the effective strain rates at model boundaries. After each fracture event, fractures in the numerical model are filled with cohesive vein material and the experiment is repeated. By systematically varying stress states, fluid pressures and mechanical properties of materials (host rock, vein infill and interface), we attempt to reproduce the characteristics of spatial distribution and thickness variation of the veins. Four parameter sets of mechanical micro-properties are defined in the models, essentially yielding (1) a competent and (2) incompetent matrix, (3) a vein material and (4) a vein-matrix interface. Each combination of parameters and particle packings is calibrated to fit a predetermined Mohr-Coulomb type failure envelope, via an automated calibration procedure. Preliminary tests already show that by varying these parameters, we are able to simulate realistically distributed cracking through crack-seal processes. Different types of veins and vein generations can be modelled, ranging from single veins, over crack-seal veins to anastomosing veins, by varying the mechanical strength of competent and incompetent matrix, vein and interface material. Further results of this approach will be presented. We will discuss our results with respect to mechanisms proposed in the literature for bedding-parallel, fibrous veins in metasedimentary rock sequences.